

The Potential of Wearable Sensor Technology for EVA Glove Ergonomic Evaluation

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BACKGROUND: Injuries to the hands are common among astronauts who train for extravehicular activity (EVA). Many of these injuries refer to the gloves worn during EVA as the root cause. While pressurized, the bladder and outer material of these gloves restrict movement and create pressure points while performing tasks, sometimes resulting in pain, muscle fatigue, abrasions, and occasionally a more severe injury, onycholysis (fingernail delamination). The most common injury causes are glove contact (pressure point/rubbing), ill-fitting gloves, and/or performing EVA tasks in pressurized gloves. A brief review of the Lifetime Surveillance of Astronaut Health's injury database reveals over 57% of the total injuries to the upper extremities during EVA training occurred either to the metacarpophalangeal (MCP) joint, fingernail, or the fingertip. Twenty-five of these injuries resulted in a diagnosis of onycholysis.

METHODS: The purpose of this study was to assess the potential of using small sensors to measure the force acting on the fingers and hand within pressurized gloves and other variables such as blood perfusion and skin temperature. A series of force sensors were placed on the fingers and hand of two test subjects while they performed static and dynamic hand tasks. Sensors to measure tactile forces were specifically placed on the finger pads of the fingertip, posterior MCP joints, and the finger nails. Tasks were performed in three conditions: (1) Ungloved, (2) Phase VI gloves and (3) Series 4000 gloves. All conditions were performed in a pressurizable glove box; with condition 1 unpressurized and conditions 2 and 3 pressurized to 4.3 psid.

RESULTS: Sensors reacted appropriately for each of the static and dynamic tasks. Depending on how the hand was used, strain gauge data revealed greater transverse strain levels for tension or compression compared to longitudinal strain, even during axial fingertip loading. Skin surface temperature was found to differ depending on location, for example, the fingertip was on average 11° F cooler than the next highest body location, the dorsum of the hand. Blood perfusion peaked and dropped as the finger deformed during finger presses, indicating an initial dispersion and decrease of blood perfusion levels at the sensor location. Force sensitive resistors to force plate comparisons showed similar force curve patterns, as fingers were depressed, indicating suitable functionality for future testing. Due to the ruggedness of the gloved environment, many of the sensors were damaged and were repaired or replaced.

DISCUSSION: Strategies for proper placement and protection of these sensors for ideal data collection and longevity through the test session were developed and should be implemented going forward for future testing. Quantifying the EVA gloved environment by assessing glove-hand forces would provide investigators with insight for determining the causation of injury. Future work should continue evaluating forces acting on the hands while including other potential risk variables found from literature such as moisture. By developing a method to quantitatively characterize levels of injury risk present in the EVA glove environment, mitigation strategies to decrease injury or pain risk can be applied to current and future glove designs.